Copy of Rutgers' model
(1966 version)

Model 1000

CURRENT INTEGRATOR

Specifications and Operating Instructions

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C O N T E N T S


| | |
|---|---|
| SPECIFICATIONS | A |
| EXTERNAL CONNECTIONS | 1 |
| OPERATING PROCEDURE | 2 |
| Amplifier zero | 2 |
| Input balance | 2 |
| Operate | 3 |
| HIGH ACCURACY AT LOW CURRENTS | 3 |
| PULSE INTEGRATION | 4 |
| Analytical method of range selection | 5 |
| Empirical method of range selection | 5 |
| OPERATING PRECAUTIONS | 5 |
| THEORY OF OPERATION | 6 |
| Amplifier zero | 8 |
| Input balance | 8 |
| CALIBRATION AND ADJUSTMENT | 9 |
| FIGURES | |
| Fig. 1 - External connections | 12 |
| Fig. 2 - Simplified block diagram | 13 |
| Fig. 3 - Connections for calibration | 14 |
| Fig. 5 - Chassis layout and transistor locations | 15 |

# MODEL 1000 CURRENT INTEGRATOR SPECIFICATIONS

## Input Characteristics

Polarity: selected by switch on front panel.
Ground: isolated from case.
Voltage Drop: less than .1 microvolt on all ranges.
Current Indication: panel meter, 1% accuracy.
Current Range: 0 to 20 ma in 15 ranges as follows:

| Range | F.S. Amperes | Input Averaging Time (sec) |
|---|---|---|
| 1 | $2x10^{-2}$ | $10^{-3}$ |
| 2 | $6x10^{-3}$ | $3x10^{-3}$ |
| 3 | $2x10^{-3}$ | $10^{-2}$ |
| 4 | $6x10^{-4}$ | $3x10^{-2}$ |
| 5 | $2x10^{-4}$ | $10^{-1}$ |
| 6 | $6x10^{-5}$ | $3x10^{-1}$ |
| 7 | $2x10^{-5}$ | 1 |
| 8 | $6x10^{-6}$ | 1 |
| 9 | $2x10^{-6}$ | 1 |
| 10 | $6x10^{-7}$ | 1 |
| 11 | $2x10^{-7}$ | 1 |
| 12 | $6x10^{-8}$ | 1 |
| 13 | $2x10^{-8}$ | 1 |
| 14 | $6x10^{-9}$ | 1 |
| 15 | $2x10^{-9}$ | 1 |

Digitizing Accuracy (Absolute)

Typically .02% F.S. .05% guaranteed on all ranges.

Reproducibility

± .005% on 1st. 10 ranges, gradually increasing to ±.02% on range 15.

Offset Adjust: ±10% of F.S current. Offset current is regulated to .01% F.S.
Peak Pulse Input Current: 20 ma on all ranges.

## Digital Output

Unit of Charge: F.S. current x $10^{-2}$ sec.
Frequency: 100 pps for F.S. current.
Output Pulse: 10V, 1.5 microsec (blocking oscillator pulse), normal polarity negative. May be converted to positive by reversing internal leads.

## Mechanical

Metal enclosure 7" x 17" with standard 19" relay-rack panel.

## Additional Features

All solid state
Front panel control converts integrator to microvoltmeter for input circuit balancing.
Reset: momentary circuit break provided to clear external counter when integrator reset button is operated.
Input and output connections accessible at front and rear of enclosure.
Output provided for driving remote current indicating meters.

## External Connections

The live and ground sides of the input current source should be connected to the "Hi" and "Lo" input terminals respectively. The "Lo" terminal may be connected to the case with the link provided on the binding post assembly or it may be left open to avoid creating a ground loop if the input cable sheath is grounded at the source.

The "Hi", "Lo" and "Case" terminals are available on the rear terminal strip as terminals 6, 7 and 5 respectively.

The digital output pulses may be applied to the counter input via the BNC connector at the front or rear of the chassis as desired.

External current indicating meters may be connected to terminals 3 and 4 of the rear strip as shown in fig. 1. Dc meters of 1.0 ma sensitivity are required. Any desired number of meters may be connected in series. To allow for variations in meter resistance, depending upon the number and type of meters used, the internal meter multiplier resistor is chosen to make the external meters read about 15% high with no additional resistance in the circuit.

When external meters are connected an external series resistor should be included as shown in fig. 2. The resistance must be adjusted to make the external meter readings agree with those of the meter on the panel. The resistance required will be about 1.5K. If desired, a 2.5K potentiometer can be inserted in the circuit and locked when the correct adjustment is reached.

Alternatively a 100μa external meter may be used with an additional 100K series resistor. The 100K resistor may then be shorted momentarily to provide high sensitivity without switching ranges for preliminary tuning of accelerators, etc.

Terminals 1 and 2 on the rear strip provide a normally-closed circuit which is momentarily opened when the Reset button is pressed. The reset line of the external counter may be connected through these terminals so that the counter will be cleared when the button is pressed. This circuit is isolated from all circuitry in the

instrument and from the case so there need be no concern about introducing ground loops if it is connected to the counter ground.

The normal digital output pulse polarity is negative. If positive polarity is desired it may be obtained by reversing the twisted pair connected to the BNC connector at the rear of the chassis.

## Operating Procedure

The adjustments for operation must be made in the following order:

1. Amplifier Zero

For this adjustment the polarity switch may be in either position and the range switch on the $2x10^{-8}$ or any higher current range. Place the Function Selector in the "amplifier zero" position and carefully adjust the Amplifier Zero control so that the panel meter reads zero. This adjustment is quite stable and normally need be made only once if the control is not subsequently disturbed. It is not affected by switching ranges but should not be made on either of the 2 most sensitive ranges because the meter sensitivity is reduced on these ranges.

2. Input Balance

The Polarity and Range switches must be set for the desired operating conditions, the target connected to the integrator input circuit and no beam applied. The Function Selector should be placed in the "operate" position and the Input Balance control adjusted until the meter reads zero. The input circuit is now roughly balanced.

The Function Selector should now be placed in the "input balance" position and the Input Balance control carefully adjusted until the meter again reads zero. In this position the residual input error is greatly magnified and the adjustment will be quite critical.

On the 3 or 4 lowest ranges, unavoidable noise in the amplifier input circuit will cause the meter to fluctuate somewhat. On these ranges the Input Balance control should be set so that the fluc-

tuations on either side of zero are equal.

3. Operate

The Function Selector should next be placed in the "operate" position. The instrument is now ready for operation. If the switch is left in the "operate" position for more than one minute before the beam is turned on, the Reset button should be pressed just prior to integration to remove any accumulated charge in the integrator capacitor which could cause an initial error of several counts. Pressing the Reset button will also clear the counter if its reset circuit is connected to terminals 1 and 2 on the rear terminal strip. If it is desired to preserve the counter content the integrating capacitor can be discharged by switching the Function Selector switch momentarily to the "input balance" position.

The counter will be observed to register counts for a few seconds after the input current ceases. These counts represent part of the integrated charge and should be allowed to register before the counter is turned off.

High Accuracy at Low Currents

If the foregoing zeroing operations are performed carefully, the integrated charge accuracy will be well within the ± .05% tolerance on any of the first 13 ranges.

On ranges 14 and 15, the inherent accuracy of the instrument is still within these limits but additional error may result because of residual unbalance in the input circuit which is masked by amplifier noise.

It should be noted that the noise having no dc component will integrate to zero and does not of itself cause error or instability in the process of charge integration. The error results from the reduced sensitivity of the "input balance" indication on the two lowest ranges. The reduction of sensitivity is necessary to keep the meter fluctuations within reasonable limits on these ranges.

If errors of .25%, .5% are acceptable on the 6 and 2 na ranges respectively, exercising reasonable care in the zeroing adjustment will suffice. If .05% accuracy is required on these ranges it can be obtained by the following procedure:

Adjust the Amplfier Zero control as previously described. With the Function Selector in the "operate" position, set the Input Balance control so that the meter reading averages about 1/4 division above zero.

Turn the counter on for several minutes (while observing an electric clock or watch second-hand or using a stop watch). Turn it off and read it.* The instrument has now been set with a constant offset of K counts per second given by $K = \frac{\text{counter reading}}{t}$ where t is the duration of the sampling period in seconds.

Integration is then performed in the normal manner and the corrected counter reading, Nc is obtained by $Nc = Na - KT$ where Na is the actual counter reading and T is the duration of the integrating period in seconds, (the actual period for which counter is on).

The offset sampling periods should not be less than three and five minutes on the 6 na and 2 na ranges respectively.

For the very highest accuracy, especially on the 2na range, it is recommended that the offset be sampled just before and just after integration and that the two values of K thus obtained be averaged to compute Nc. Samll drifts caused by temperature changes which occur during integration will thus be averaged out.

The offset sampling and integrating periods need not be measured with extreme accuracy since the offset for a meter reading of 1/4 division above zero is only about 1% of the full scale current reading. A 1% error in the value of K would therefore represent an integration error of only .01% F.S.

*Alternatively the counter may be left on and counting started and stopped by switching the Function Selector from the "input balance" position to the "operate" position and back.

## Pulse Integration

The Model 1000 Integrator is capable of integrating pulsed input currents, even of very low duty factor, with essentially the same accuracy as dc inputs.

The set-up procedure is the same as that for dc operation. Care must be observed, however, to avoid error due to overloading of the input amplifier.

The first precaution is that the peak current, applied to the input on any range, never be permitted to exceed 20 ma.

The second precaution is that the current range be chosen so that the output voltage capability of the input amplifier is not exceeded. The correct current range may be determined analytically or empirically as follows:

Analytical Method: For almost all pulsed input conditions the optimum current range will be the lowest range which will satisfy the following inequality (1):

$$(1) \quad I_{fs} \geq \frac{Q_p e^t}{e^t - 1}$$

Where $I_{fs}$ = current range (amperes),

$Q_p$ = charge contained in each input pulse (coulombs),

t = pulse repetition period (seconds),

e = 2.718.

The above expression is valid for all cases where the indicated minimum for $I_{fs}$ does not exceed $2\text{x}10^{-5}$ A. If a value higher than $2\text{x}10^{-5}$ A is indicated then the current range must be chosen to satisfy inequality (2):

$$(2) \quad I_{fs} \geq \frac{2\text{x}10^{-5}}{t} \log_e \frac{2\text{x}10^{-5}}{2\text{x}10^{-5} - Q_p}$$

Empirical Method: The optimum current range for a given pulsed input may be determined by observing the voltage on terminal 4 of the rear terminal strip (external meter disconnected) on an oscilloscope with the pulsed input applied and selecting the most sensitive current range which will not cause the peak voltage to exceed -10V (+ 10V on terminal 3 for negative inputs). The oscilloscope must have dc response so that the maximum true voltage to ground is observed. The oscilloscope ground should be connected to the "Lo" input terminal.

Precautions

If a fluctuating current is to be integrated it is important to choose a current range higher than the maximum anticipated beam current because input currents in excess of full-scale will not

be integrated, resulting in error.

The input circuit is protected by a pair of silicon diodes so that accidental input currents as high as several hundred ma can be tolerated on any range without permanent damage to the instrument. Currents of over 25ma, however, will saturate the input amplifier and charge the chopper filter capacitor, disabling the instrument for several minutes. If this difficulty occurs, the cure is simply to leave the Function Selector in the "operate" position and wait until the meter settles to zero. A protective diode feedback network in the input amplifier insures that such saturation will not occur at input currents up to 25 ma even on the $2 \times 10^{-9}$ A range.

The electrical ground ("Lo" input terminal" of the integrator may be connected to the chassis by use of the grounding link at the input terminals or it may be connected to any other point of definite potential in the experimental system provided that the potential difference between the "Lo" input terminal and chassis is never permitted to exceed 50 volts. Never attempt to apply input current to the integrator with the "Lo" terminal floating.

## Theory of Operation

Symbols used in the following explanation of operation refer to the block diagram, Fig. 2. This diagram is provided for explanatory purposes only and is greatly simplified. Provisions for polarity switching are not shown and the explanation, except where noted, will assume positive input current.

Chopper-stabilized amplifier A1, together with $R_1$, the resistive feedback network delivers an output voltage which is proportional to the input current. The output voltage is of polarity opposite to that of the input current and is equal to -10 volts for full-scale positive input on any range. Pulse inputs are averaged by the capacitor $C_1$, selected by $S_1$. The input balancing current is applied to the amplifier input via resistor $R_2$ which is also selected by $S_1$.

The output voltage of $A_1$ is read by the panel meter to indicate the input current.

Resistor R3, capacitor $C_2$ and amplifier $A_2$ comprise a Miller integrator which is used to integrate the output voltage of $A_1$.

$A_2$ is also an inverting amplifier so that the output voltage of $A_2$ rises for positive currents at the input of $A_1$. When the output voltage of $A_2$ reaches about +2 volts the amplitude discriminator "enables" gate 1 and the flip-flop is triggered to the "on" state by the next trigger pulse from the pulse shaper. The switching diode $D_1$ now passes a precisely controlled 2 ma current to the summing point of $A_2$. This current is of opposite polarity to that resulting from the output voltage of $A_1$ and drives the output of $A_2$ downward, thereby neutralizing the effect of the input signal. The neutralizing current persists for five msec until the next trigger pulse switches the flip-flop to the "off" state. At this time the output of $A_2$ will be between zero and -2.5 volts depending upon the input current and will begin to rise again if input current is still flowing. Each time the output of $A_2$ reaches 2 volts the process is repeated. At full scale input the flip-flop switches at every trigger pulse and neutralizing pulses are delivered to the summing point at the rate of 100 per second.

The value of the neutralizing current is determined by $R_4$ and the voltage of the zener diode, $Z_1$. The duration of each neutralizing pulse is determined by the period of the 200 cycle fork. Since $R_4$, $Z_1$, and the fork are all precision, temperature-compensated components, the quantity of charge delivered during each neutralizing pulse is precisely determined.

Each time the flip-flop is switched into the "on" state to produce a neutralizing pulse the blocking oscillator is triggered to produce one digital output pulse.

Both $A_1$ and $A_2$ have an output range of $\pm$ 10 volts. When negative inputs are to be integrated, the polarities of the amplifier outputs are opposite to those of the foregoing explanation. Under these conditions the panel meter, zener voltage source and switching diodes must be reversed and the positive amplitude discriminator $Q_{23}$ replaced by negative amplitude discriminator $Q_{22}$. These operations are performed by switching the Input Polarity switch to the negative position.

## Amplifier Zero

When the Function Selector is in the "amplfier zero" position the input of $A_2$ is grounded through a resistor (to simulate its normal driving-source impedance), the feedback impedance of $A_2$ is changed from capacitor $C_2$ to resistor $R_5$ and the meter is switched to read the output voltage of $A_2$. The output of $A_2$ is disconnected from the amplitude discriminator to prevent the application of neutralizing pulses to the input of $A_2$. Under these conditions the output voltage of $A_2$ will be zero when the amplifier input circuit is properly balanced. The balancing operation is performed by adjusting the Amplifier Zero control, a variable resistor in the collector circuit of the input stage of $A_2$.

## Input Balance

When the Function Selector is in the "input balance" position, the input of $A_2$ is connected to the output of $A_1$. Since the feedback impedance of $A_2$ is again resistive and the meter is still connected to the output voltage of $A_2$, $A_2$ now functions as an electronic voltmeter reading the output voltage of $A_1$. $A_1$ is chopper-stabilized and its input offset voltage is essentially zero. Its output voltage, however, will generally not be equal to zero because of thermal emf's and possible leakage currents in the external current source. The Input Balance control is adjusted to apply a current of proper polarity and amplitude to compensate for these effects.

When the Function Selector is anywhere but in the "operate" position, the integrating capacitor, $C_2$, is shorted so that when the switch is moved to the "operate" position there is no residual charge in $C_2$. Even the most minute unbalance in $A_2$, however, can cause $C_2$ to become charged if the Function Selector is left in the

"operate" position long enough. This is the reason for the previous recommendation that the Reset button be pressed just prior to integration if the Function Selector has been in the "operate" position for more than one minute and very high accuracy is desired. Alternatively, if the external counter reset feature is used and it is desired not to clear the counter, $C_2$ may be discharged by switching the Function Selector momentarily to the "input balance" position.

## Calibration and Adjustment

The resistive feedback network mounted on the Range switch determines the current-to-voltage conversion factor of the input amplifier $A_1$ and therefore the relative sensitivity on each range. All of the resistors used on ranges 1 through 12 are aged, stabilized, wire-wound resistors of .01% tolerance and are not adjustable. Because of the high values required on ranges 13, 14 and 15 the resistors used on these ranges are low T.C. metal film units. They are trimmed to the exact values required by additional trimming resistors mounted on the board supported by $S_1$. The metal-film resistors, although of looser initial tolerance than the wire-wound units, possess the same order of stability and should never require adjustment.

The overall sensitivity is determined by the setting of the 1K precision trimmer $R_{4A}$, (calibration control). This adjustment affects the sensitivity equally on all ranges.

The temperature-compensated reference diode used to determine the amplitude of the neutralizing current pulses is of the highest obtainable quality. The diode is "burned in" at the factory to eliminate aging effects and to enhance long-term stability. It should not drift more than a few hundredths of 1% during several years of operation.

If recalibration is ever required it may be accomplished if the following items are available.

1. A voltage source of 1 volt which is stable and accurate to .01%.

2. A 50,000 ohm resistor of .01% accuracy.
3. A voltmeter with a range of approximately 3 volts dc. High accuracy is not required.
4. A 1 megohm carbon resistor.

The calibration should be performed as follows:

1. Remove the top cover.
2. Connectthe 1 meg resistor across the integrating capacitor. The capacitor terminals are available at the 2 upper terminals of the reset switch so the bottom plate need not be removed.
3. Connect the voltmeter (in either polarity) between terminal 2 of the rear wafer of the Range switch ($S_1$) and the chassis. (The switch terminals are numbered clockwise, viewed from the rear, with the rotor contactor being designated #1.)
4. Connect the voltage source and the 50K resistor to the input terminals as shown in fig. 3. The left-hand of the resistor should be switched or clipped to ground initially.
5. Place the Input Polarity switch in the "positive" position, the range switch in the $2x10^{-5}$ A position and the Function Selector in the "amplifier zero" position.
6. Carefully adjust the Amplifier Zero control until the voltmeter reads zero.
7. Place the Function Selector in the "input balance" position and carefully adjust the input balance control until the voltmeter again reads zero.
8. Switch the Function Selector to the "operate" position.
9. Remove the left hand end of the 50K resistor from ground and connect it to the voltage source. Disregard the voltmeter reading at this time.
0. Remove transistor $Q_{23}$ from its socket. After a few seconds the voltmeter sould settle to very nearly zero. The residual reading represents the calibration error with a proportionality factor of 1V = 0.1%.
1. Adjust the calibration (green) trimmer until the voltmeter reads exactly zero. This adjustment is extremely critical and must be made very slowly and carefully.

12. Replace $Q_{23}$ and remove the voltage source from the input. The calibration is now complete. Turn the instrument off, disconnect the 1 meg resistor and voltmeter and replace the cover.

Note:

The preceding calibration procedure depends for its accuracy upon the accuracy of the tuning fork frequency, which is $\pm$ .02%. If a really meticulous calibration is desired, the possible .02% error caused by the fork can be eliminated as follows:

a) Measure the fork frequency by removing $Q_{23}$ and observing the digital output frequency with a very accurate frequency meter or a counter gated by a crystal controlled clock. This measurement should be made to .001% accuracy.

b) Compute correction voltage, $V_s$ by $V_s = 10\ (100-f)$ where f is the digital output frequency.

c) Follow the preceding calibration procedure but at step 11, set the calibration trimmer to yield a voltmeter reading of $V_s$ rather than zero.

Example: $f = 100.012$ cps, $V_s = 10\ (100 - 100.012) = -.12V$

In this case the integrator would be perfectly calibrated when the residual meter reading referred to in steps 10 and 11 was -.12 volts. Similarly a frequency of 99.984 cps would call for a residual meter reading of +.16 volts.

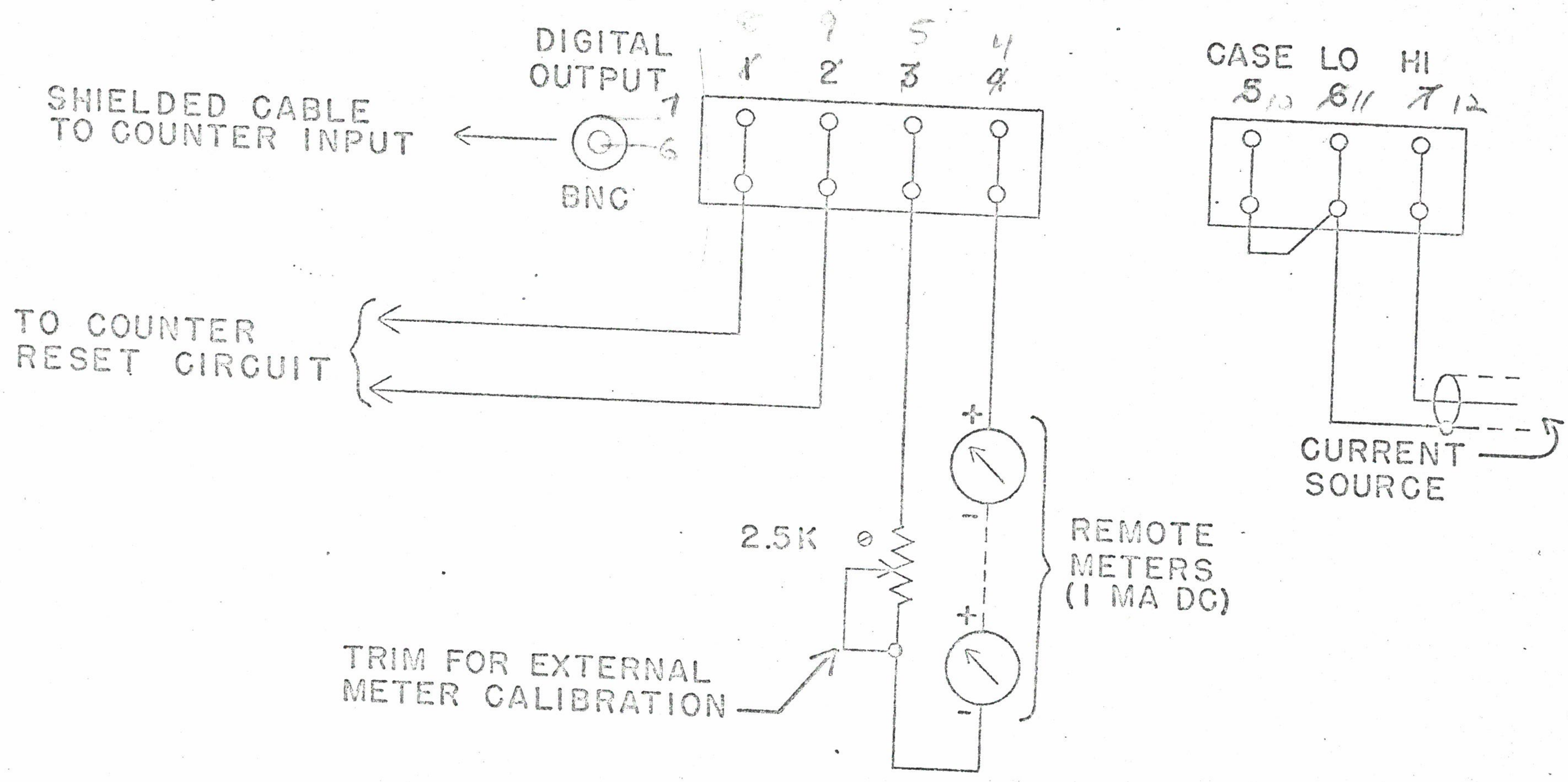



FIG. 1 - EXTERNAL CONNECTIONS USING REAR TERMINAL STRIP.

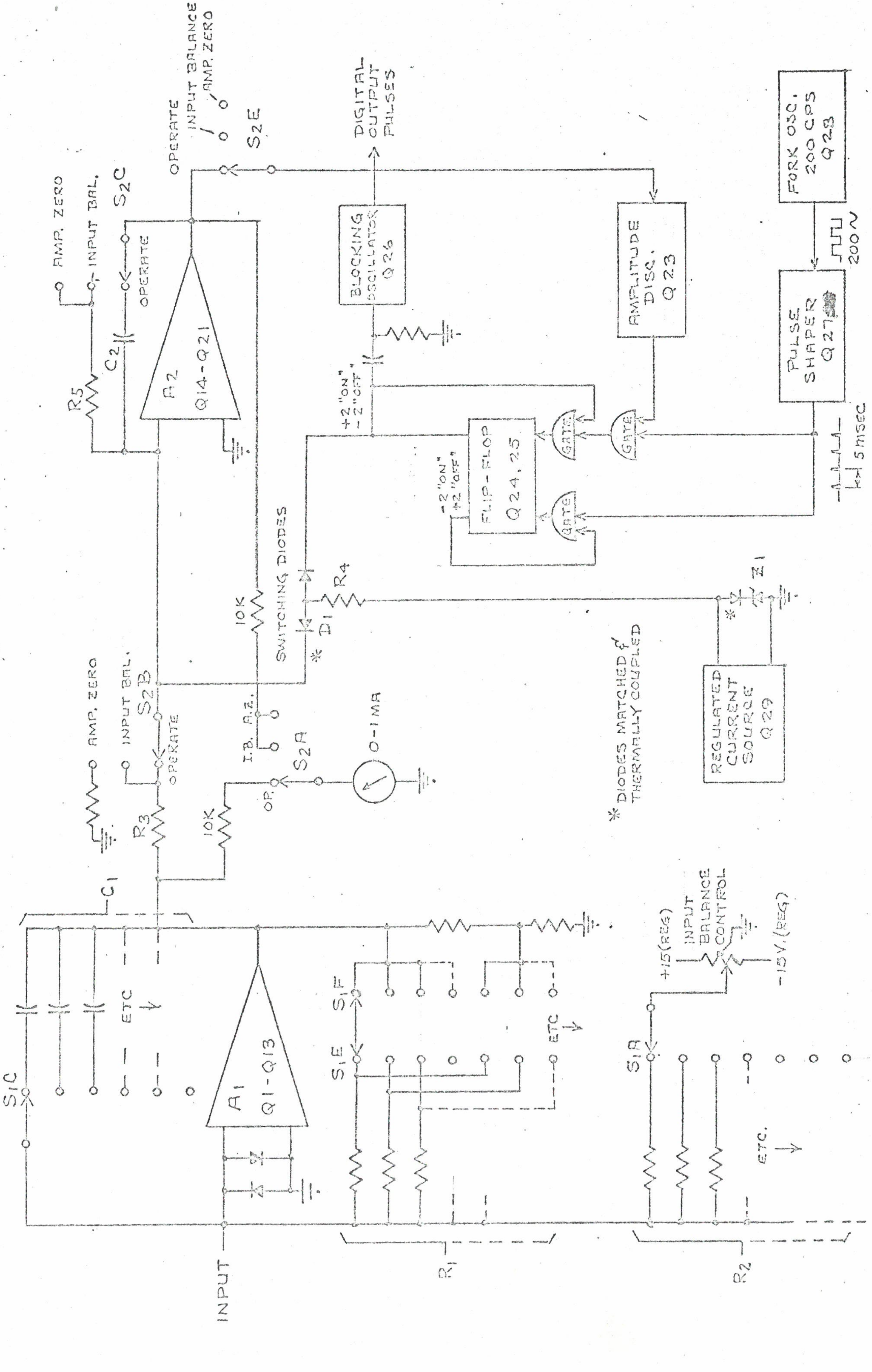



FIG. 2 - MODEL 1000 CURRENT INTEGRATOR
SIMPLIFIED BLOCK DIAGRAM

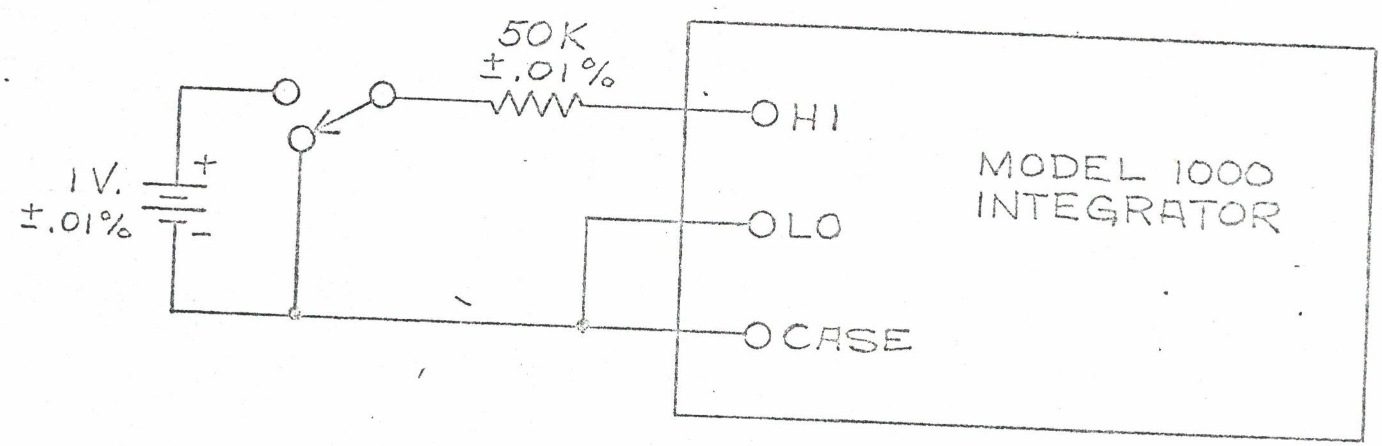
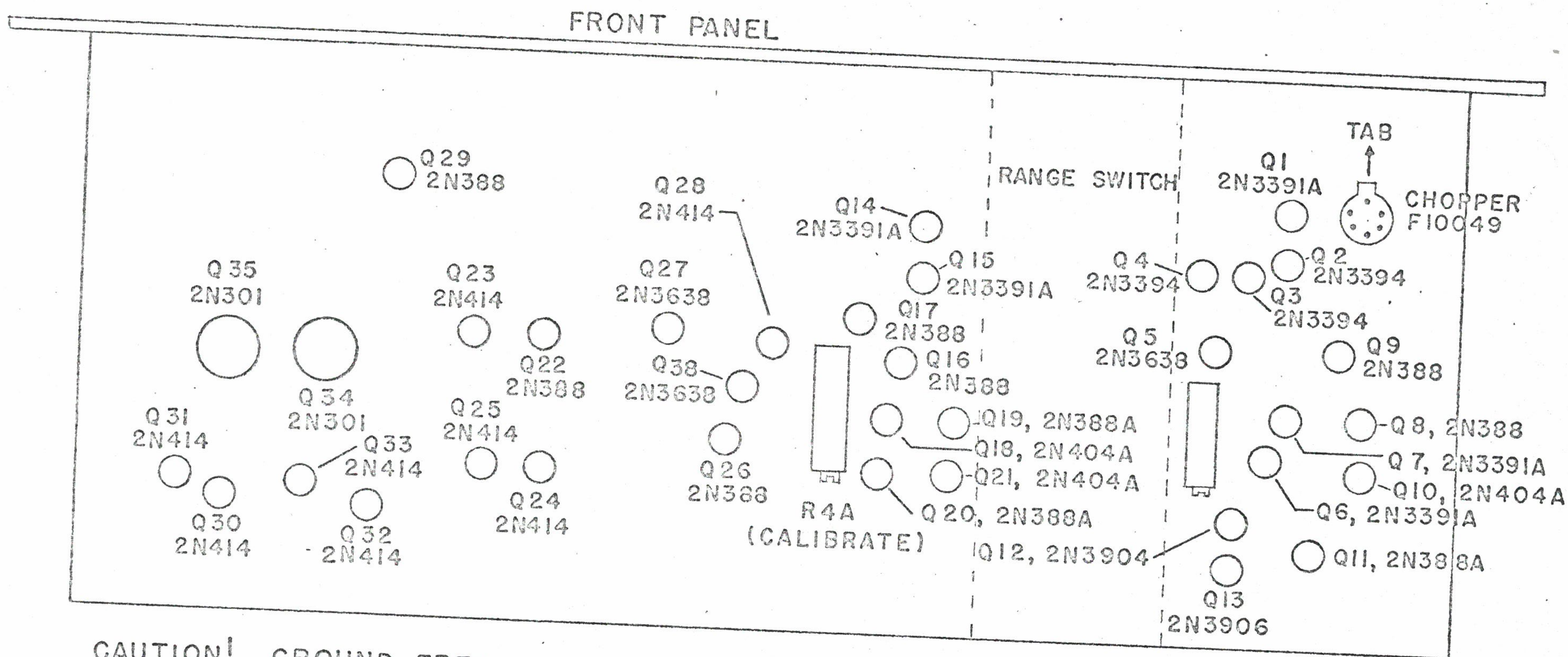


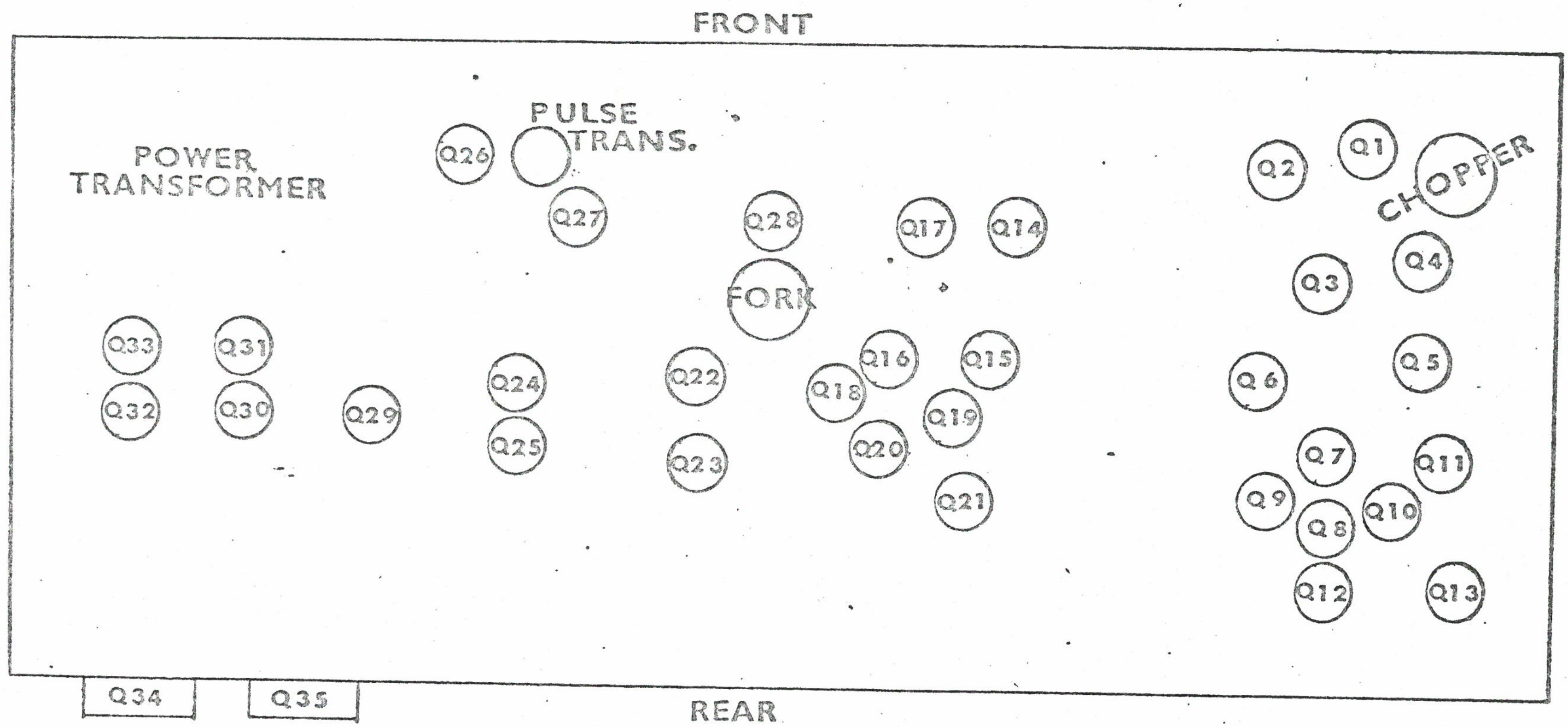

FIG. 3 - CONNECTIONS FOR CALIBRATION




CAUTION! GROUND FREE HAND TO CHASSIS WHEN REMOVING OR REPLACING F10049. FAILURE TO DO SO MAY RESULT IN DESTRUCTION OF DEVICE BY ELECTRO-STATIC CHARGES.

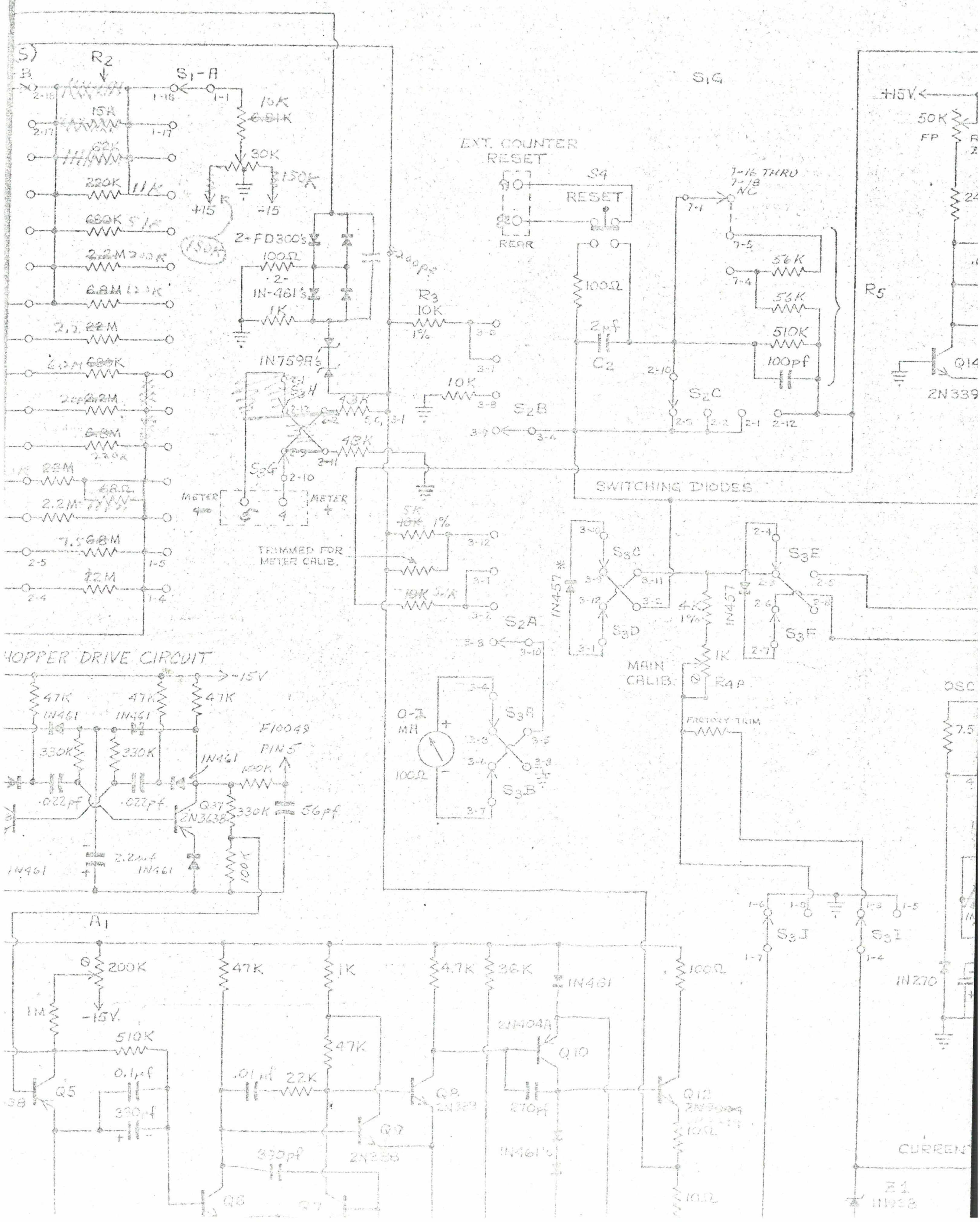
FIG. 4 TRANSISTOR LOCATIONS (TOP VIEW)

Not valid for ser #'s before 2004. Earlier units have transistor #'s on underside of board.

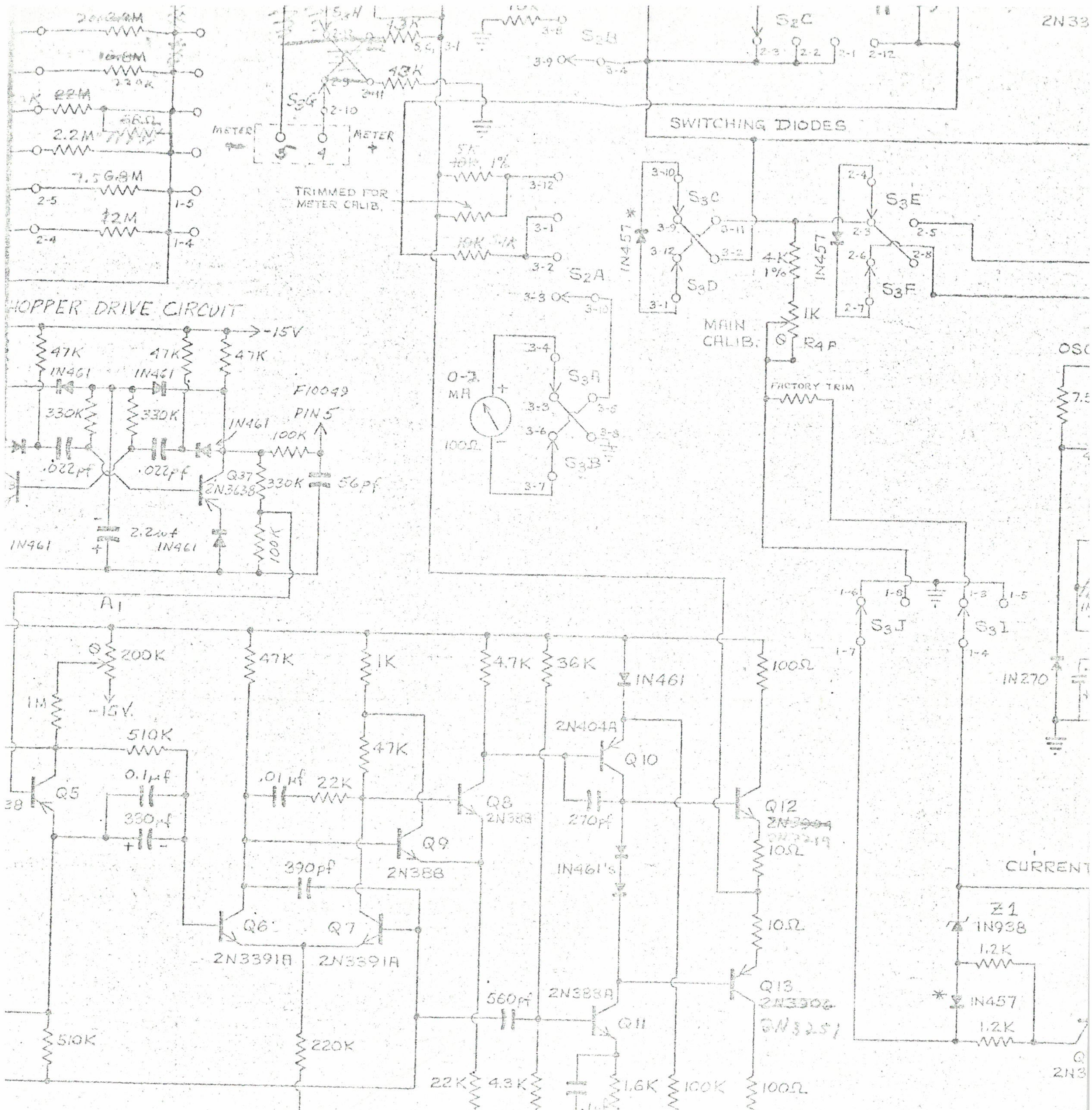



TOP CHASSIS TRANSISTOR POSITIONS

FIG. 4



R2
S1-A
10K
6.81K
30K
150K
+15
-15
2-FD300's
100Ω
2-
IN-461's
1K
IN759A's
S2H
S2G
METER -
METER +
TRIMMED FOR METER CALIB.
R3
10K
1%
43K
S2B
S2A
EXT. COUNTER RESET
S4
RESET
REAR
100Ω
2μf
C2
S1G
7-16 THRU 7-18 NC
56K
510K
100pf
R5
S2C
SWITCHING DIODES
+15V
50K
FP
Q14
2N339
S3C
S3D
S3E
S3F
IN457
4K
1%
1K
MAIN CALIB.
R4P
FACTORY TRIM
0-1 MA
100Ω
S3A
S3B
S3J
S3I
OSC
HOPPER DRIVE CIRCUIT
-15V
47K
IN461
330K
.022pf
2.2μf
Q37
2N3638
F10049
PIN 5
100K
56pf
A1
200K
1M
-15V
510K
0.1μf
330pf
Q5
47K
.01μf
22K
1K
Q8
Q9
2N388
330pf
Q6
4.7K
36K
IN461
2N404A
Q10
270pf
IN461's
100Ω
Q12
10Ω
IN270
CURRENT
Z1
IN938



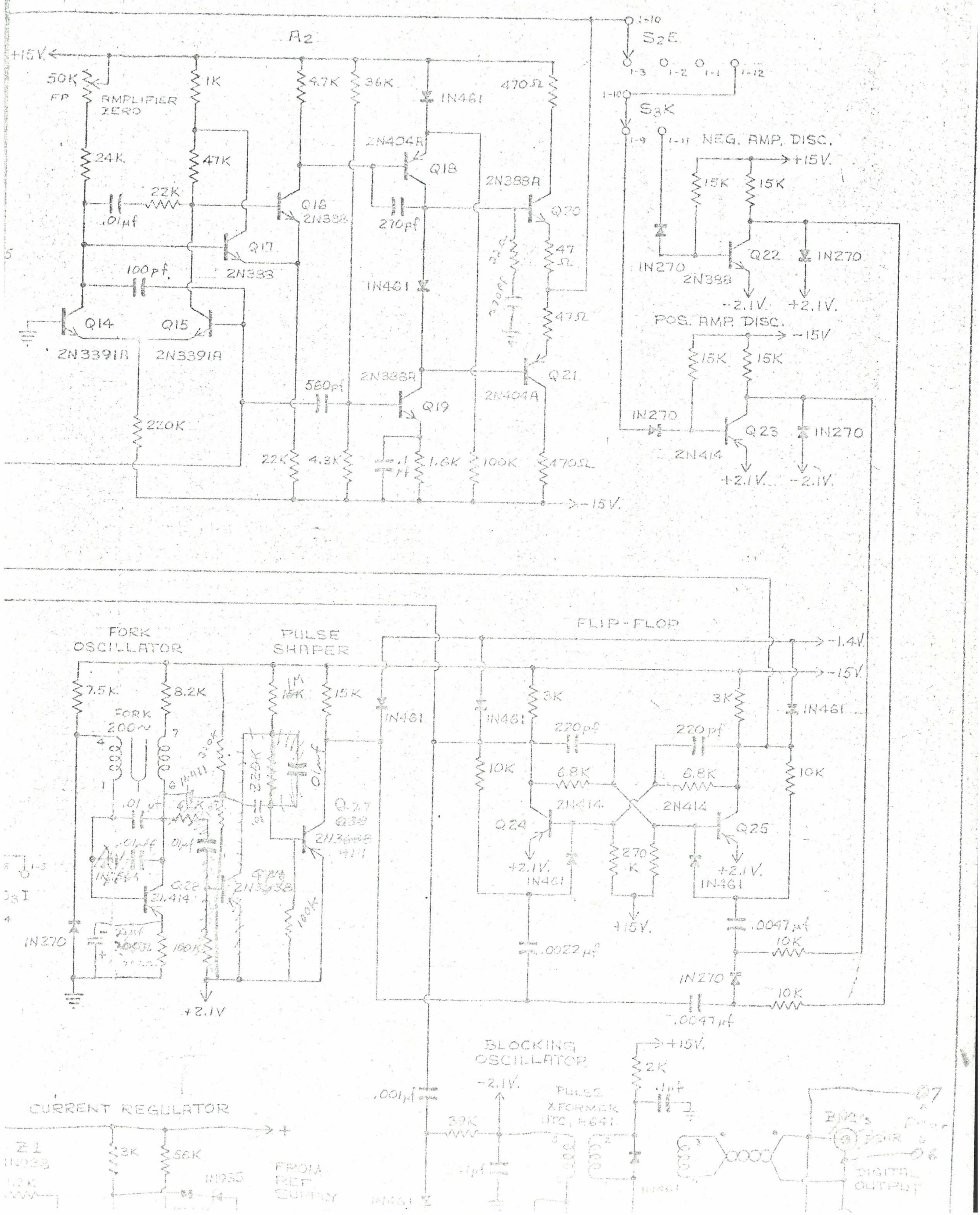

CIRCUIT NOTES:

SWITCH NOTE:

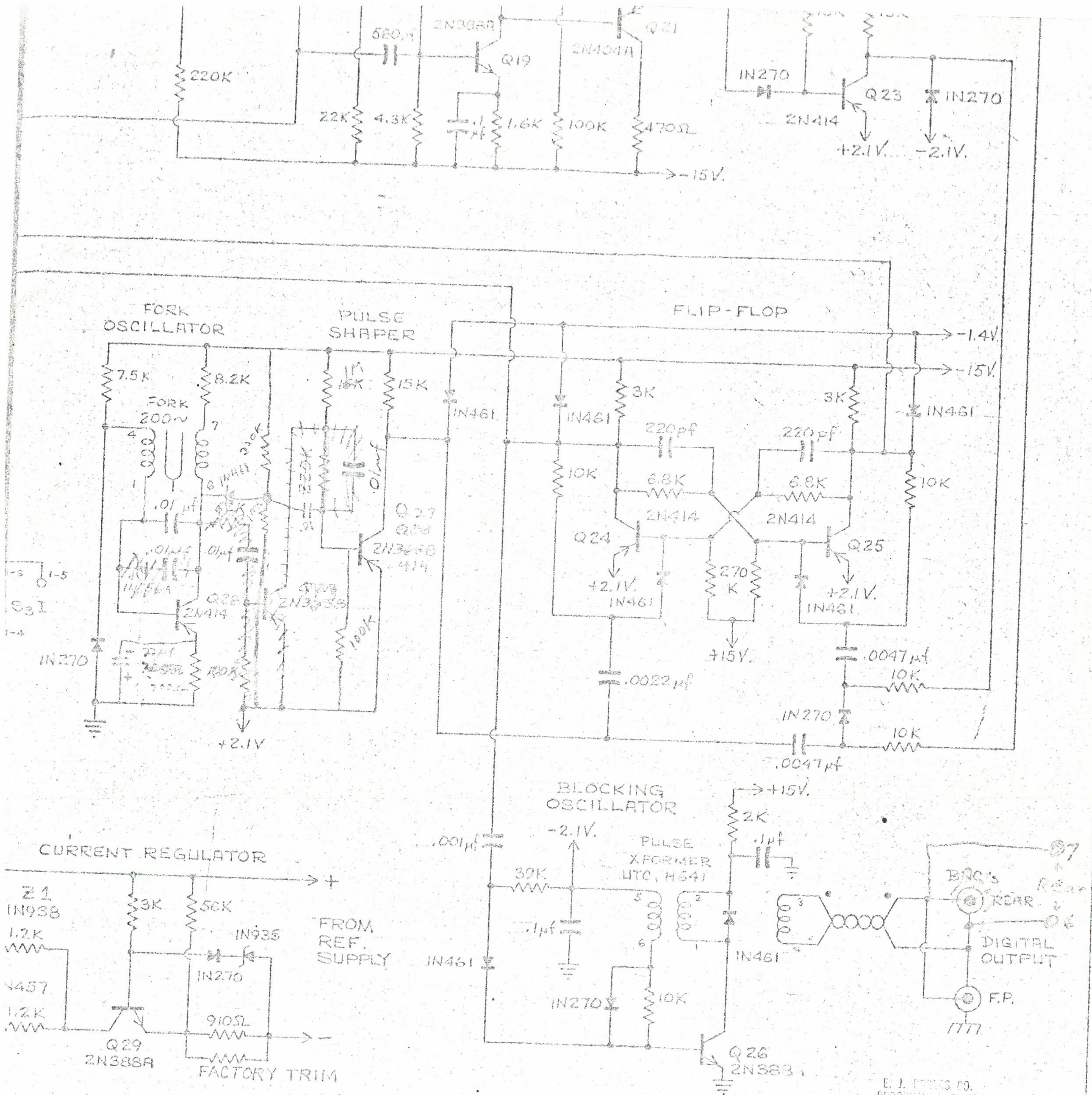
$S_1$ - SHOWN IN $2 \times 10^{-2}$ A POSITION

$S_2$ - " " AC OFF POSITION

$S_3$ - " " POSITIVE INPUT POSITION



A2
+15V
50K
FP
AMPLIFIER ZERO
1K
4.7K
36K
IN461
470Ω
24K
47K
2N404A
Q18
22K
.01µf
Q16
2N388
270pf
2N388A
Q20
Q17
2N388
47 Ω
100pf
47Ω
Q14
Q15
2N3391A
2N3391A
560pf
2N388A
Q19
Q21
2N404A
220K
22K
4.3K
1.6K
100K
470Ω
-15V
S2E
S3K
1-10
1-3
1-2
1-1
1-12
1-9
1-11
NEG. AMP. DISC.
15K
IN270
Q22
2N388
-2.1V.
+2.1V.
POS. AMP. DISC.
-15V
IN270
Q23
2N414
+2.1V.
-2.1V.
FORK OSCILLATOR
PULSE SHAPER
FLIP-FLOP
-1.4V
7.5K
8.2K
FORK 200~
15K
IN461
3K
220pf
10K
6.8K
2N414
Q24
Q25
270 K
+15V.
.01µf
Q27
100K
IN270
100K
+2.1V
.0022µf
.0047µf
10K
.0047µf
BLOCKING OSCILLATOR
-2.1V.
+15V.
2K
PULSE XFORMER
.001µf
39K
CURRENT REGULATOR
3K
56K
FROM REF SUPPLY
DIGITAL OUTPUT




NOTES:

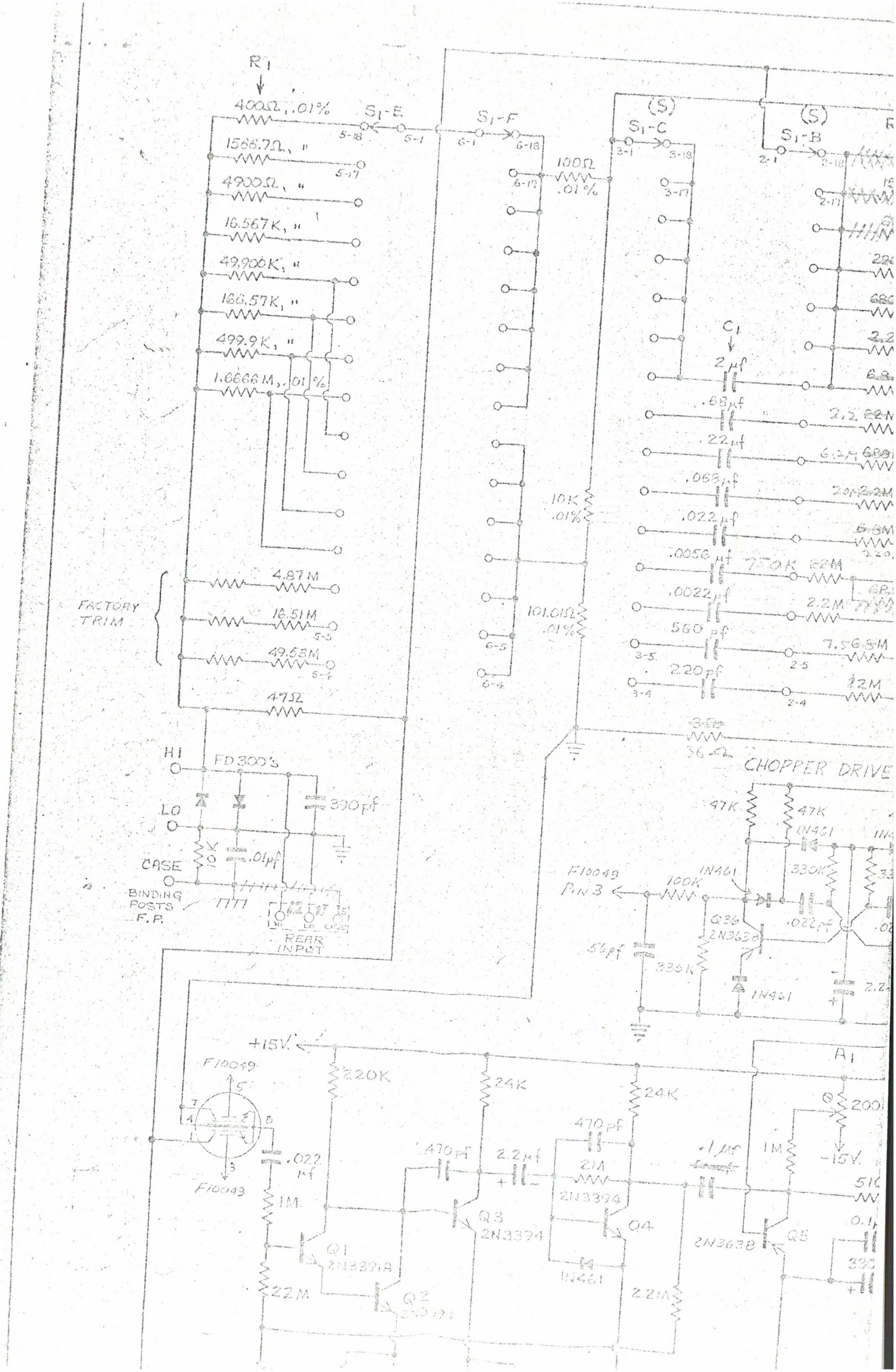
1- * DIODES MATCHED & THERMALLY COUPLED.

2- SYSTEM GND. - OFF CHASSIS.

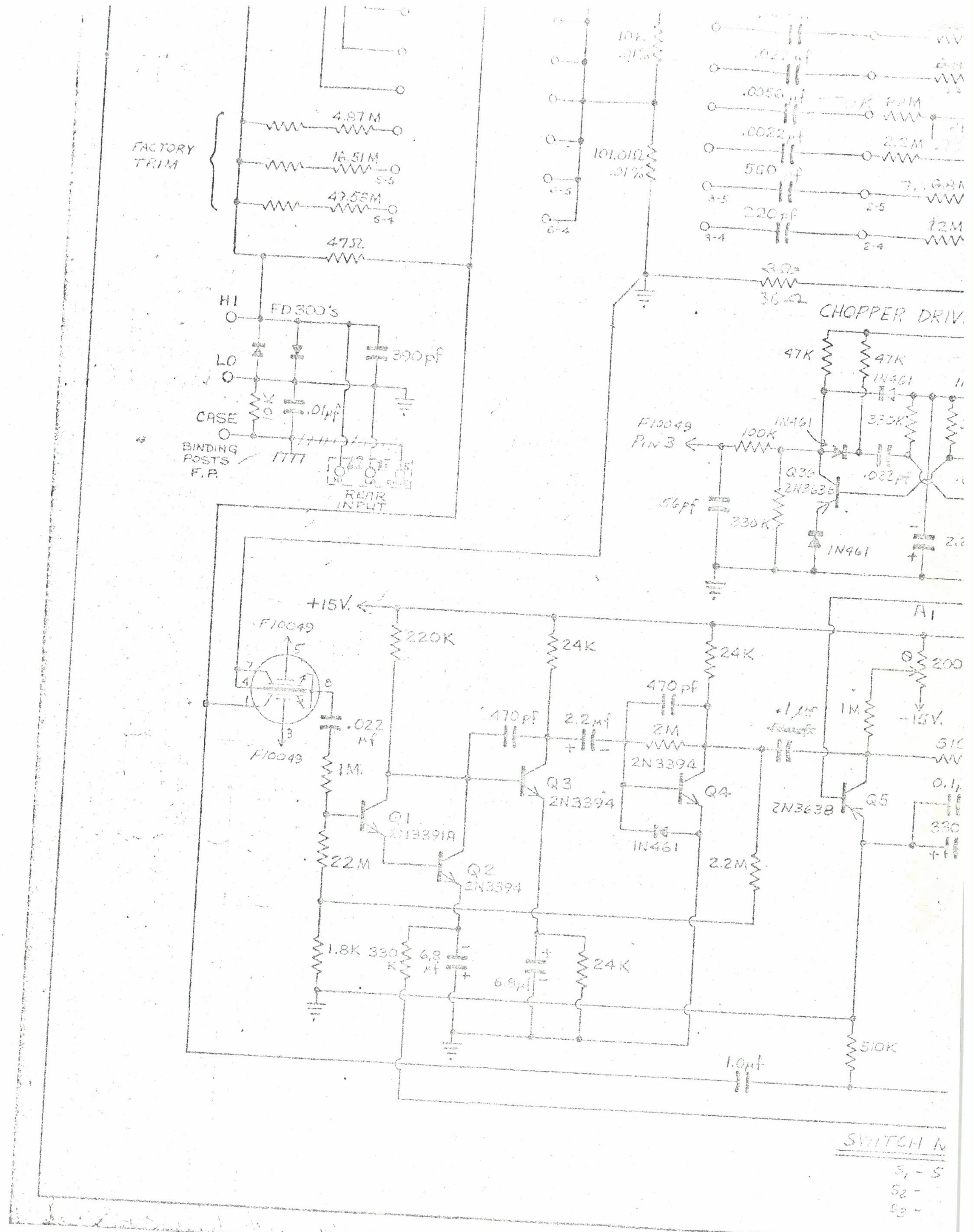
3- CHASSIS GND.

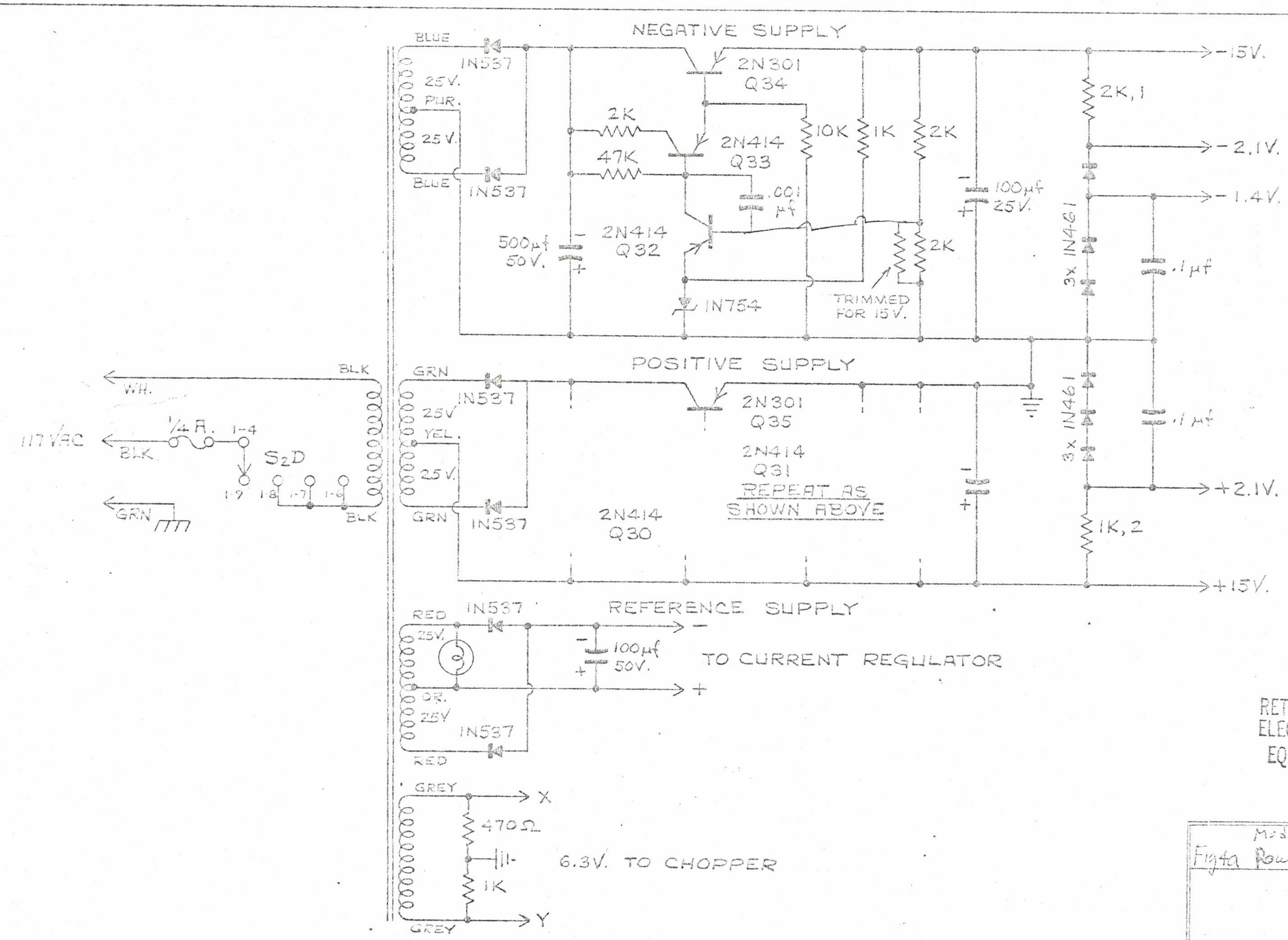
E. J. BROOKS CO.
BROOKLYN, N. Y.

Model 1000 Current Integrator Ser# 2001
Revised 4/16/66



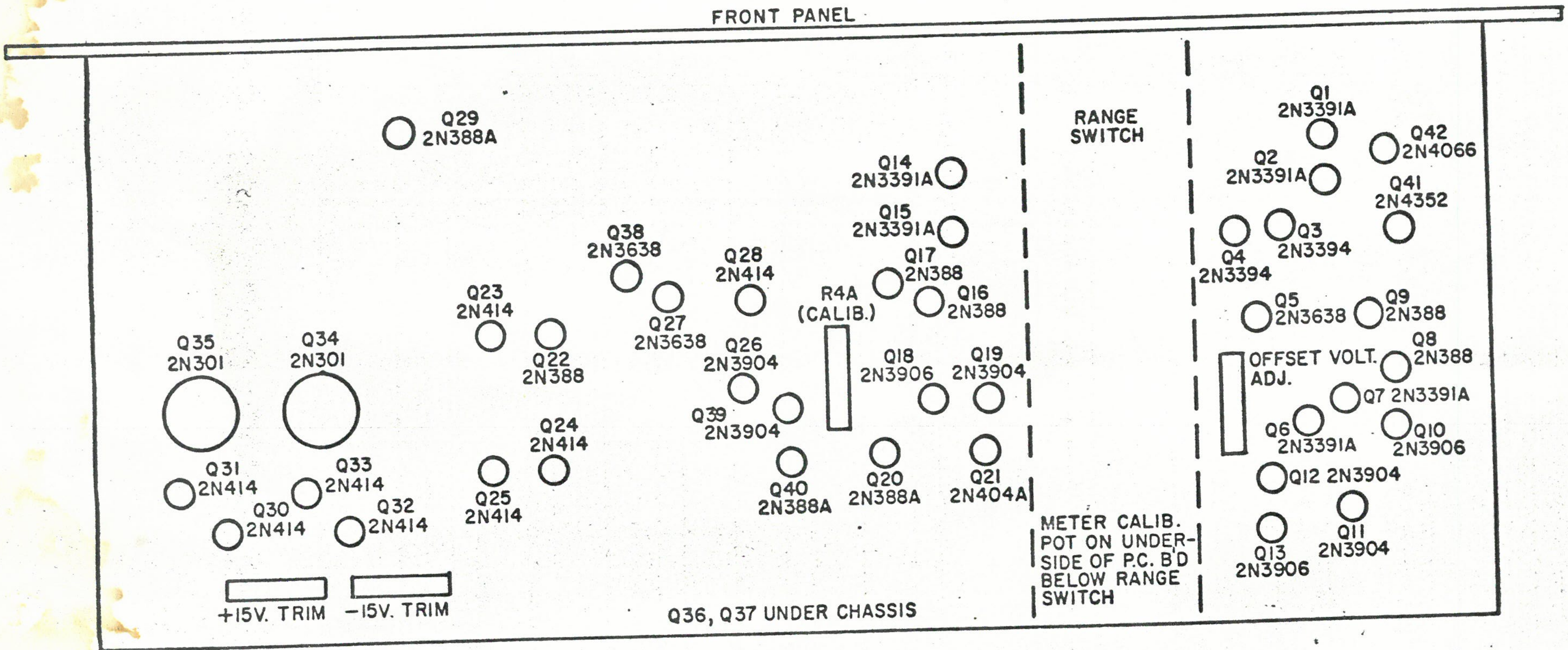
R1
400Ω, .01%
1566.7Ω, "
4900Ω, "
16.567K, "
49.906K, "
166.57K, "
499.9K, "
1.6666 M, .01 %
S1-E
S1-F
S1-C
S1-B
100Ω .01%
10K .01%
101.01Ω .01%
C1
2 μf
.68 μf
.22 μf
.068 μf
.022 μf
.0056 μf
.0022 μf
560 pf
220 pf
750K
22M
2.2M
FACTORY TRIM
4.87 M
16.51 M
49.53M
47Ω
36 Ω
HI
LO
CASE
FD300's
390 pf
.01 μf
BINDING POSTS F.P.
REAR INPUT
CHOPPER DRIVE
47K
1N461
330K
100K
F10049 PIN 3
Q36 2N3638
.022 μf
56 pf
+15V
220K
24K
A1
F10049
.022 μf
1M
22M
Q1 2N3391A
Q2
470 pf
2.2 μf
Q3 2N3394
Q4
2N3394
21K
2.21K
.1 μf
2N3638
Q5
1M
-15V


FACTORY TRIM
4.87M
16.51M
47.53M
47Ω
HI
LO
CASE
FD300'S
390pf
.01µf
BINDING POSTS F.P.
REAR INPUT
10K .01%
101.01Ω .01%
.022µf
.0056µf
.0022µf
560pf
220pf
2.2M
12M
36Ω
CHOPPER DRIV
47K
47K
1N461
330K
F10049 PIN 3
100K
Q36 2N3638
.022µf
56pf
330K
1N461
+15V.
220K
24K
24K
F10049
470pf
470pf
2.2µf
2M
2N3394
.022µf
1M
Q1 2N3391A
Q3 2N3394
Q4
1N461
22M
Q2 2N3394
2.2M
1.8K
330K
6.8µf
6.8µf
24K
A1
200
1M
-15V.
2N3638
Q5
.1µf
510K
1.0µf
SWITCH
$S_1$ - S
$S_2$ -
$S_3$ -




RETURN TO NPL
ELECTRONIC SHOP
EQUIPMENT FILE

Model 1000 Integrator
Fig 4a Power Supply Schema




**CAUTION!** GROUND FREE HAND TO CHASSIS WHEN REMOVING OR REPLACING Q41 OR Q42, FAILURE TO DO SO MAY RESULT IN DESTRUCTION OF DEVICE BY ELECTROSTATIC CHARGES.

FIG. 3 TRANSISTOR LOCATIONS (TOP VIEW)